4-2019

Smart Solutions to Control Air pollution in Dubai - Al Qouz area

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RIT

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A Capstone Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Professional Studies - City Sciences

Department of Individualized Study

Rochester Institute of Technology

Rochester, New York

RIT Dubai

April 2019

RIT

Master of Science in Professional Studies - City Sciences

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Capstone Title: Smart Solutions to Control Air pollution in Dubai -Al Qouz area

Area: Air quality and environment

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ABSTRACT

Air pollution is a major concern, both in industrial and developing countries. Measuring and monitoring air pollution is mandatory to have a smart and clean environment. By the recent developed technology such as Internet of Things (IoT), levels of poisonous gases (GHG) are measured and controlled, which will help in having healthier atmosphere and help people whose life are endangered from living near polluted areas. The project proposes to use smart sensors to sense and measure the percentage of polluted gases like CO, CO_2, SO_2 and NO_2. Since Dubai aims to achieve the best results of having the least effect on the climate change and to improve the air quality in the city, this project will help having a better air quality standard for the citizens.

The main objective in this project is to install highly accurate sensors in Shaikha Latifa Bent Hamdan Street in al Quoz residential area 3&4 which is opposite to al Quoz industrial area 1&2, where factories produce GHG gases. The level of each of the GHG gases will be measured and compared to the threshold that is set by the authorities. If the measured value is higher than the threshold, the responsible authorities, like Dubai Municipality, will be informed and thus appropriate correction actions shall be taken by the authority and the factories.

This project introduces an overview of the IoT concept and uses interconnected smart sensors to collect and analyze the data. Moreover, this project will explain the process of how the sensors measure the amount of pollution and propose recommendations to be taken based on the collected data.

KEYWORDS: Atmosphere, Pollution, Sensors, Climate change, Smart city, Smart solution.

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1. Problem background

Technologies have advanced to a level where it has not been before, and it is still advancing in taking huge steps towards the future. Humans have been building big cities and modern facilities for citizens' luxury. However, they are focused more on the new technologies and the luxurious lifestyle rather than the citizens, animals and the environment surrounding them. Cars, air-conditioners, human waste and industries lead to an increase in the carbon emissions in the environment. This pollution causes climate change, long term diseases, imbalance in the eco system, etc.

According to The World Health Organization, air pollution is defined as "the presence of materials in the air in such concentration which are harmful to man and his environment".[1] Which basically means that air pollution is any harmful substances in the atmosphere which causes damage to the environment, human health, and the quality of life. With the expansion of the industrial sector, an increase in the air pollution came along that occurs inside and near homes, schools and offices even in the countryside. Air pollution is broadly classified into particles and gaseous. Some of the major gases that may concern the public health are Carbon dioxide, ozone, Nitrogen dioxide and Sulphur dioxides.

- Carbon Dioxide (CO2):

CO2 is emitted naturally by the ecosystem in moderate concentration. However, its concentration has increased dramatically by human activity, like; cars emission and power generation stations emissions, which made it harmful by trapping heat and causing global warming. [2]

- Carbon Monoxide (CO):

Mondale stated that, CO is responsible for 50% of the total atmospheric pollutants. The incomplete burning of various fuels, including coal, wood, and natural gas can produce CO. It is colorless, odorless, and one of the most lethal and deadliest gases since it could combine with hemoglobin of blood and impairs its oxygen carrying capacity. [3]

- Sulphur Dioxides (SO2):

SO2 is a colorless gas or liquid with a strong, choking odor. It is formed from the burning of fossil fuels and the manufacturing of mineral such as (aluminum, copper, zinc, lead, and iron) that contain sulfur. Additionally, it is a major component of acid rain. [4]

- Nitrogen Oxides (NO):

According to U.S national library of medicine, Nitrogen Oxides is a gas with a sharp, sweet smell; it is colorless to brown at room temperature. It is created by human activities in combustion process of industries, automobiles, incinerators and nitrogen fertilizers. [5]

Industrial pollution affects the growth of plants, crops and animals, thus reducing natural resources. In addition, affect the human health by causing disease such as: asthma, Cancer, Fever, Skin rashes, and Respiratory diseases.

To build a smart environment which would serve and facilitate good life and make it healthier and safer to live in, this project attempts to reduce the air pollution that is caused by industrial activities to improve the air quality. Smart sensors will be used to measure the amount of pollution in the air. If the pollution exceeds the limits then authorities would be informed about it, and appropriate actions towards the violations would be performed.

According to Gulf news, “Dubai aims to establish itself as the world’s smartest city that provides unparalleled quality of life for its residents and visitors through smart technology. These involve six key thrusts — smart life, smart transportation, smart society, smart economy, smart governance and smart environment”. [6] This means that Dubai is expected to be one of the smartest cities in the region and worldwide.

The aim of this project is to reduce the air pollution in the industrial areas due to the waste the industrial sector causes and the poisonous gases it produces. The plan is to make our environment smart not only by gathering the data of gases status in the industrial area, but also by sending these data to the concerned authority to take appropriate actions.

Two projects were found, which have similar objectives as this project. The first one is in Stockholm and the other is in Lebanon.

Case Study 1:

BeitMisk management installed an Air quality application based on IoT technology throughout the residential area in BeitMisk to preserve a healthy lifestyle. The goal is to bring more awareness to the environment, giving the users the possibility to know when it is the best time of the day to go outside. In addition, it will reduce the air pollution by planning any activity or project construction. The gathered data will help them to maintain a better control of traffic within the community. It will measure the following air quality parameters:

- Temperature, humidity and atmospheric pressure
- Carbon monoxide (CO)
- Nitrogen dioxide (NO2)
- Sulfur dioxide (SO2)
- Ozone (O3)
- Particle Matter (PM1, PM2.5, PM10)

BeitMisk management managed to promote healthy lifestyle and control power in Lebanon by monitoring and gathering data of the air quality in the residential area. The project was implemented and reached its goals successfully; the gathered data was continuously flowing to a platform that provides real time data for the users. From this project we can be sure that the project will be a success, since both projects have similar goals such as: gathering air quality data, streaming real time data for monitoring and controlling to maintain clean atmosphere. [7]

Case Study 2:

Stockholm implemented a sensor network to monitor the air pollution in the city. Pollution monitoring in city center of Stockholm and displaying these data for the citizens have raised public awareness and showed the effectiveness of municipalities and public institutions actions. The results of this project are interesting. There were a 22% reduction in CO_2 emissions and 18% traffic jam average time reduction. They monitored the following parameters to determine the quality of the air we breathe:

- Nitrogen dioxide (NO_2)
- Carbon dioxide (CO_2)
- Carbon monoxide (CO)
- Methane (CH_4):
- Hydrogen sulfide (H_2S)
- Hydrocarbons (Ethanol, Propane, Butane, Isobutane, Toluene):
- Ozone (O_3)

This project was simple and cost effective due to its features of wireless communication via the protocol 802.15.4 / Zigbee and battery power source that can be recharged using a solar panel. We believe our project will successfully achieve its goals as this project, since both projects are planning to reduce the air pollution by controlling and monitoring the emission of the industries by displaying these data for the responsible organization and authority. [8]

2. Description and goals

The goal of this project is to utilize the IoT technology in monitoring and controlling air pollution, and to collect pervasive data about the air quality in specific area in Dubai. Additionally, the focus will be on air pollution caused by the industrial activities of factories, which is one of the main causes of air pollution. This project's goals are compatible with the objectives of UAE EAI (Environmental Assessment Impact), which offers information to decision makers regarding matters related to the environment, that will influence decisions related to new projects, programs, plans or policies. The project will use smart sensors, IoT technology and data analysis to have a smart and healthy city, which means to have more comprehensive intelligent services. This will encourage factories to be more efficient by using environmentally friendly equipment and machines, that will minimize energy, waste and resource consumption, and help to attain a higher quality of life by ensuring higher air quality for the residents. The test area for this project is 3.23 kilometers of Shaikha Latifa Bent Hamdan Street. This street is located between Al Qouz residential areas 3 and 4 and Al Qouz industrial areas 1 and 2 as it is shown in Figure1.

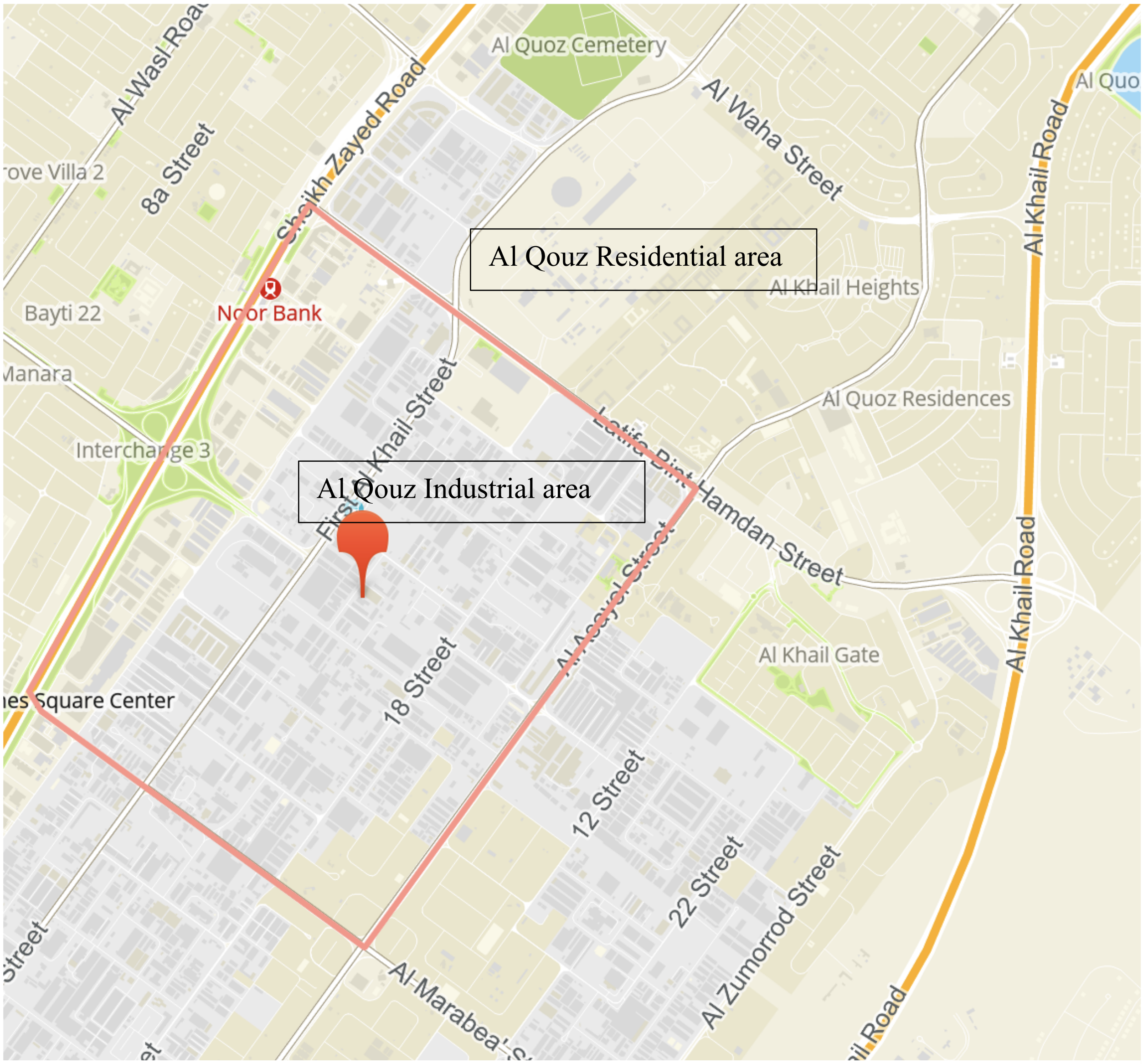


Figure 1: Test Area Map

Other related project goals are:

1. To increase Dubai air quality index
2. To reduce the number of industrial violations
3. To reduce the number of casualties caused by air pollution such as: asthma.
4. To reduce the effect of the global warming and climate change.

3. DELIVERABLES

This project aims to utilize smart systems for Dubai environment that provides safety and improves the quality of air through IoT technology. So, we need to build a complete IoT system that can be applied outdoors to monitor and control the air pollution, through collecting real time data using microcontroller device and gas sensors. The data will be collected from the sensor nodes that are distributed in Latifa Bint Hamadan street for detecting air pollution in al Qouz industrial areas 1&2. The measured data will be analyzed in a gateway database. Then depending on the results of the analyzed data, the responsible government agency will make decisions accordingly.

3.1 Capturing Data

More details on data capturing equipment's:

a) Waspmote is a microcontroller board that is used in the project. The microcontroller is shown in Figure 2. The Waspmote is a device that creates a wireless sensor network

Figure 2: Waspmote Microcontroller

- It can be implemented outdoors since it has a longer lifetime span than the usual microcontrollers such as: Arduino boards.
- It is designed for various combination of communication models, such as Zigbee, and 802.15.4, etc.
- Waspmote board can hold more sensors than a regular Arduino.

b) Gases sensor board v3.0 will be plugged onto Waspmote board where the sensors are going to be connected to. The gas sensor board is shown in Figure 3. This will create a sensor node, where it can be placed outdoors for sensing gases.

Figure 3: Gases Sensor Board

Waspmote gas sensor board is designed to monitor environmental parameters such as temperature, humidity, atmospheric pressure and 14 different types of gases. It allows the inclusion of 7 gases sensors at the same time, Figure 4, shows the socket inputs that are designed for specific gas sensors of the gas sensors in the gas sensor board.

There is a dedicated socket for each of the following sensors:

- Temperature, Humidity, Air Pressure
- CO2 (Socket 1a)
- Air Pollutant I (Socket 3b)
- Air Pollutant II (Socket 2b)

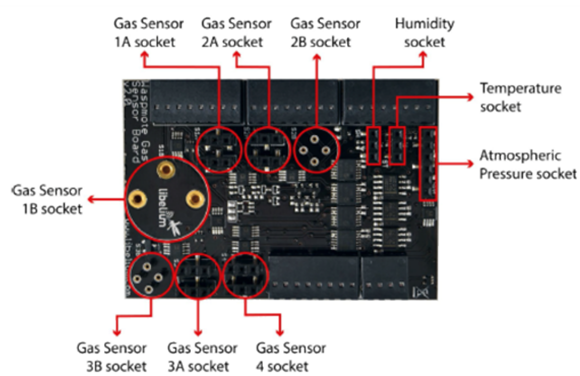


Figure 4: Socket Placements in Gas Sensor

c) Sensors Specification:

Table 1 shows the sensors specification regarding its sensitivity and the response time.

Sensor	Sensitivity	Response Time
CO2	44 ~ 72mV	1.5 minutes
Air pollutant I	0.15 ~ 0.5	30 seconds
Air pollutant II	0.3 ~ 0.6	30 seconds
Temperature	10mV/Co	1.65 seconds
Pressure	46mV/kPa	20ms

Table 1: Sensors Specification

d) The Meshlium gateway, shown in Figure 5 that receives data from the Waspmote. It serves as a local database for the data that are being received.

Figure 5: Meshlium Gateway

- It can contain 4 different radio frequency communications, and they are; a Wi-Fi 2.4 GHz (Access Point), a 4G/3G/GPRS/GSM and 2 XBee/RF radios.
- Meshlium also integrates a GPS module for mobile and vehicular applications.
- It is designed to endure the different types of atmosphere.

3.2 Communication

The pre-calibrated gas sensors will be interfaced with Zigbee/802.11 module through the gas sensor board. The Data that is collected from the gas sensors are packetized and sent to a gateway (Meshlium; which is an IoT gateway that may contain up to 4 different radio interfaces) which is directly connected with the sensors, for storage in the database or to the internet server when available, using ethernet protocol (IEEE 802.15.4 IEEE 802.15.4 Xbee-PRO). The Sensor Parser software, that comes with Meshlium Gateway, will be used to convert the data frames sent from the sensors nodes and to store the Data in the local database (cloud) and synchronize the local database with any connected external database used by the authorities through 3G.

Referring to Figure 6 for the project, the communication technologies techniques will be chosen based on the application and in this project IEEE 802.15.4 Zigbee protocol is the best choice. (See appendix A- the communication interface specification).

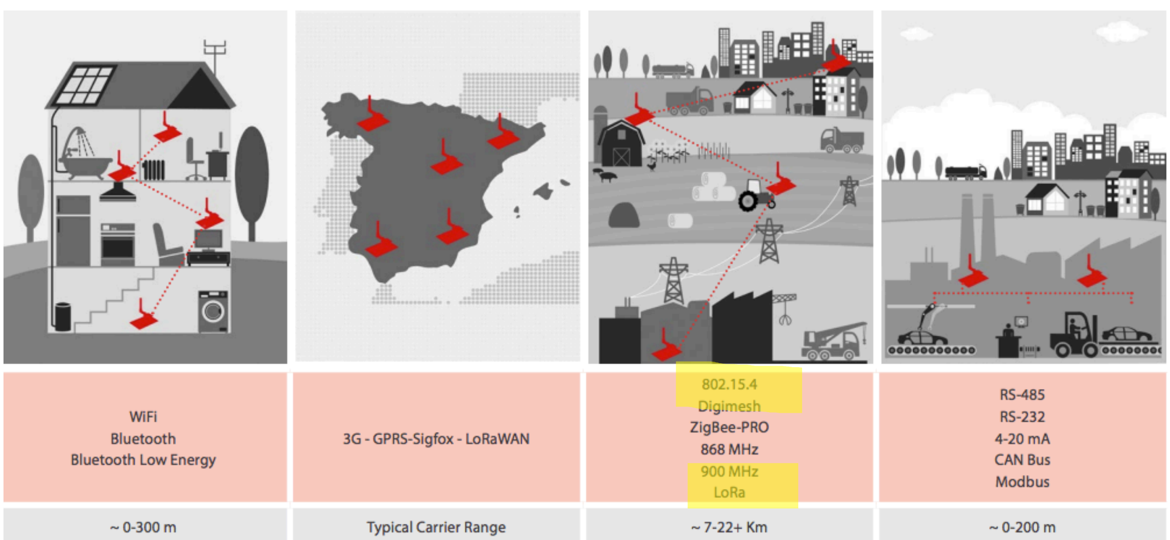


Figure 6 : Communication Techniques

3.3 Data Analysis

The Type of Data Analysis used in the project is the descriptive analysis, which is "the discipline of quantitatively describing the main features of a collection of data". [9] In essence, this type of analysis describes a set of data that is captured by different sensors in regular basis. Its main function is to compare the captured data to the assigned threshold for each gas to monitor its level in the air. It is the simplest type of analysis, since all that is utilized from the collected data is monitoring the industrial activities that affect air pollution and to maintain or improve the air quality.

Once the data is collected centrally, the system needs to make sense of it to form actionable insights. For instance, data from gases sensors could indicate the percentage of pollution in certain areas.

Moreover, the data will be kept in the cloud to be used in comparing readings in monthly, yearly or even daily bases as needed and to ensure that air pollution is decreasing over the time. Also, to involve the residents in Al Qouz community in improving the air quality of the area, the data will be used to show the progress in attractive charts and diagram with helpful advice for the residents such as; encouraging public transportation, cycling or walking.

In Table 2, the threshold for each of the gases responsible for air pollution and which affect human health is shown. These thresholds will be used as the set point in this project.

Table 2: The maximum allowable emission limits for each gas

Substance	Symbol	Sources	Maximum Allowable Emission Limits (mg / Nm3)
Carbon Monoxide	CO	All sources	500
Sulfur Dioxide	SO2	Combustion Sources Material Producing Industries Other Sources	500 2000 1000
Sulfur Trioxide including Sulfuric Acid Mist (expressed as Sulfur Trioxide)	SO3	Material Producing Industries Other Sources	150 50
Ammonia and Ammonium Compounds (expressed as ammonia)	NH3	Material Producing Industries Other Sources	50 10

Carbon	C	Odes Production Waste Incineration	250 50
Carbon dioxide	CO_2	atmospheric concentration	between 350ppm and 2000ppm

3.4 Design Process

The final step is to use the analysis above to make decisions, solutions or influence people behavior to change.

3.4.1 Target Group

The gathered data analysis will target two type of groups:

3.4.1.1 Decision Makers/ Authority

a. The alarm system is to be initiated when the value of the measured pollutants is above predetermined thresholds, so that when gases' concentration does exceed the threshold, the alarm system could take several actions that warn the surrounding people, and it can also inform concerned government party, so that they take actions towards the violation.

b. The collection of data will create risk register data that will be used in risk assessment to develop an action plan by the concerned authorities to solve, modify or create new regulations. Moreover, the factories will be informed to reduce their activities or manage their production of the GHG gases.

c. A risk management strategy might be considered. In order to take precautions against air pollution and its harmful effects, and make study plans and strategies for the future (see appendix B).

3.4.1.2 Residence

An awareness dashboard that will be implemented in the street in partnership with RTA or Dubai Police to monitor the air quality. In addition, residents can be warned if there is a piousness gas leakage in the atmosphere.

3.4.2 Design Process Summary

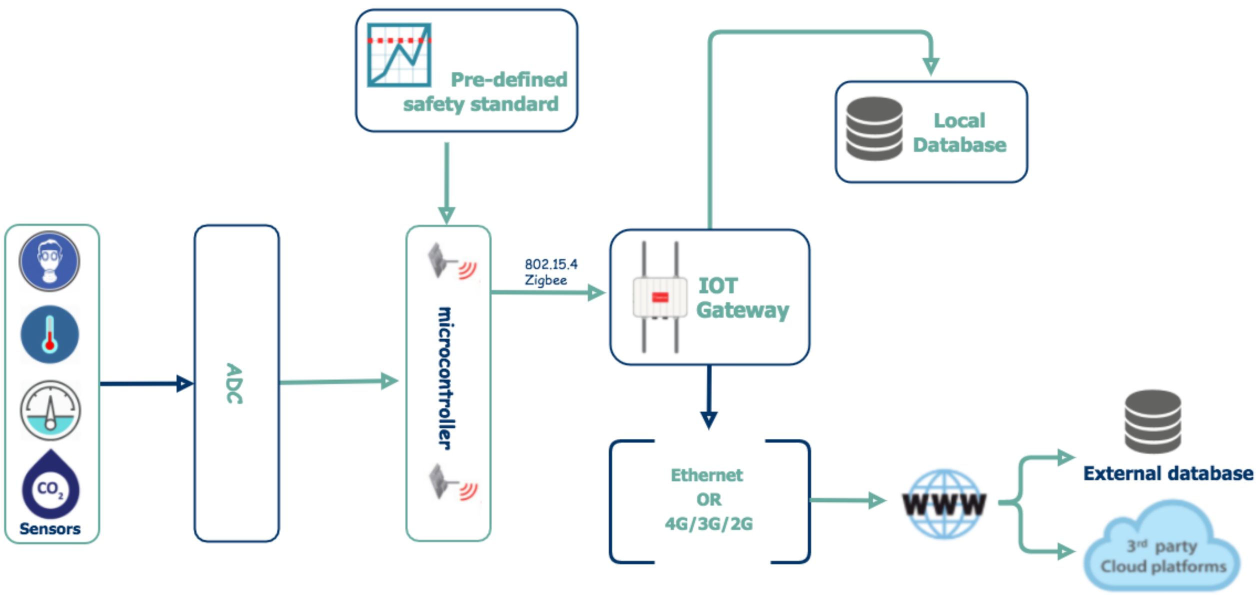


Figure 7: Design Process

Figure 7 summarizes the complete wireless sensor network for monitoring air pollution. The sensor node, which is the microcontroller, has to be connected to the battery as a power source and XBee module (IEEE 802.15.4 Zigbee protocol) as a means of wireless communication. A number of 12 gas sensor nodes will be placed in Shaikha Latifa Bent Hamdan Street to gather data of air pollution concentration in the environment. The gathered data will go through analog to digital converter (ADC)system that converts an analog signal into a digital signal so it can be transformed though Zigbee. The sensors will be programed depending on pre-determined value in the table1. Then Data from the sensor nodes are sent to an IoT gateway using the IEEE 802.15.4 Zigbee protocol. The data will be saved in the local database of the gateway, also it can be sent to an external database/the web using Ethernet or 3G interface.

3.4.3 Project Flow Chart

Figure 8 describes the flow of the signal acquired from the implemented sensors in the desired areas. Once the microcontroller is initiated, the sensors will start reading and gathering the data of air pollution. These gathered data will be analyzed and compared to the pre-determined thresholds in the microcontroller for each gas. When the pollution is below the thresholds, the sensors will keep reading data continuously. However, if the pollution increases beyond the pre-determined thresholds then the sensor node can use this data in the mentioned applications.

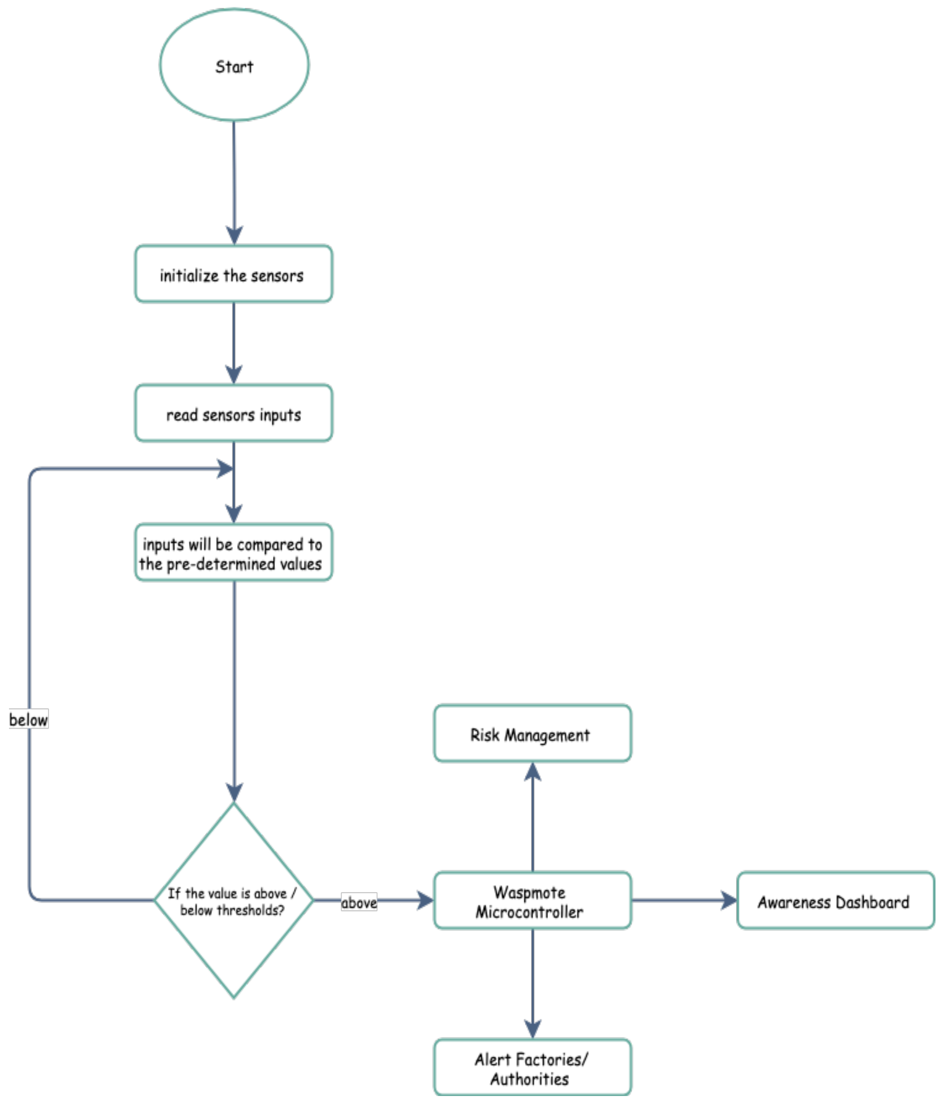


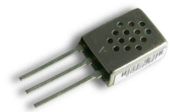
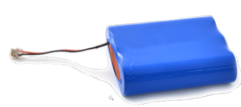
Figure 8: Project Flowchart

4. BUDGET

Getting all the required components will cost around $ 1923.15. Table 3 shows the cost and the quantity for each component.

Table 3: Cost and quantity for sensors

Components	Picture	Quantity	Cost
Microcontroller		2	273.78$
XBee-PRO 802.15.4		2	371.88$
Air Pollutants I (NH3, H2S, CH3-CH2-OH, C6H5CH3) Gas Sensor		2	50.18$
Air Pollutants II (CH4, CO, CH-CH3, H2, CH3-CH2-OH) Gas Sensor		2	45.62$
Temperature sensor		2	9.12$

Humidity sensor		2	54.76$
Air Pressure Sensor		2	57.04$
CO2 Gas Sensor		2	125.48$
IoT Gateway		1	787.01$
6600mA·h battery		2	68.44$
Solar panel 7.4V		2	79.84$
Total Cost			1923.15 $

Since the street we will implement the nodes is Latifa Bint Hamdan Street, which is 3.23 kilometres long. We believe that we need 2 microcontrollers to cover this street, because we are using a communication module (XBee-PRO 802.15.4) that covers (1600 m). Moreover, with this IoT gateway we are able to store the data in the local database or send it to an external database using WIFI/GSM. Also, we are trying to cover all the toxic gases which are emitted from the industries such as: Co2, NH3, CH4, CO, CH-CH3, H2 and CH3-CH2-OH. Furthermore, we are using a solar panel to reduce the energy usage and to be more sustainable.

5. Evaluation

The outcomes of the project are to implement an automated system that helps monitoring and controlling the use and the results of the pollution gases to ensure both safety and health for users. The system will collect data of different GHG gases, temperature and humidity then sends them wirelessly to the gateway for monitoring. To prove the accountability of the project, there are direct and indirect pillars to measure before and after the implementation. The direct factors are improved air quality in the area by reduced GHG gases and control the amount of pollution coming out of the factories. Indirect factors could be measured by reduced number of diseases caused by pollution specially for the people living near the industrial areas. Moreover, the project will be a useful tool for the authority to change or improve their policies and regulations.

6. Appendix

Appendix A:

Communication Interface Specification

» 802.15.4 / ZigBee

Radio version	Protocol	Frequency	Tx power	Sensitivity	Range*
XBee-PRO 802.15.4 EU	IEEE 802.15.4	2.4 GHz	10 dBm	-100 dBm	750 m
XBee-PRO 802.15.4	IEEE 802.15.4	2.4 GHz	18 dBm	-100 dBm	1600 m
XBee-PRO DigiMesh	DigiMesh	2.4 GHz	18 dBm	-100 dBm	1500 m
XBee ZigBee S2D	ZigBee-Pro v2007	2.4 GHz	8 dBm	-102 dBm	1200 m
XBee 868LP	RF	863 - 870 MHz	14 dBm	-106 dBm	8.4 km
XBee-PRO 900HP US	RF	902 - 928 MHz	24 dBm	-110 dBm	15.5 km
XBee-PRO 900HP BR	RF	902 - 906.8 MHz 915.6 - 928 MHz	24 dBm	-110 dBm	15.5 km
XBee-PRO 900HP AU	RF	915.6 - 928 MHz	24 dBm	-110 dBm	15.5 km

* To determine your range, perform a range test under your operating conditions.

Figure 9 - Communication Interface Specification [10]

Appendix B:

Environmental Pollution Risk Management Report

1. Introduction

The risk management report includes a plan to identify the risks that might happen and the actions that are needed to overcome or to mitigate the unwanted impacts on the continuity of the environment pollution. The risk management plan is prepared to achieve the following objectives:

1. To overcome or to mitigate the threats that might occur.
2. To identify the possible risks and determine the effective reactions, weather reporting to authority, sending attention alarm SMS, keep the public far away from the source, report to factory or unintended sources, or destroy the pollution sources.
3. To enhance the performance of protecting the environment from gas pollution in reducing the possible risks.
4. To reduce the cost of risk management to prevent the impacts on the financial security.
5. Eliminate and detect possible practices and conditions that might lead to have possible risks.

The environmental pollution risk management report will identify the potential risk sources; assess individual risks and impacts on performance; evaluate alternative approaches to mitigate high and moderate risks; and develop action plans to handle individual risks.

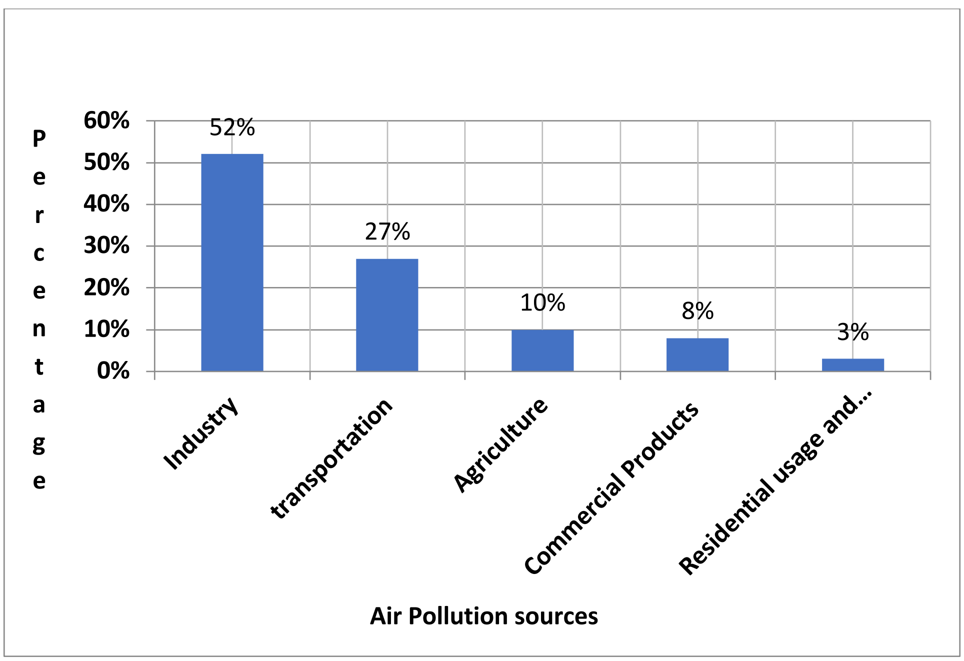
2. Air Pollution

It is known that air is a mixture of several gases like nitrogen (79%), oxygen (20%), and noble gases like argon, carbon-dioxide (1%). As air is a mixture the composition and proposition of the gases varies time to time depending upon the places, e. g., industrial areas have more probability of pollutant gas emission than urban areas. Air pollution is the state where air gets polluted with high concentration of chemicals which will usually harm living beings and cause serious damage to non-living beings.

3. Major Sources of Air Pollution

Fig. xx shows the contribution of each industrial, household, commercial and agricultural sector for air pollution. It’s clear from the chart that industrial sectors pollute more the environment at a rate of 52% percentage. When the industries are taken into account probably the textile sector account for 17-20% of the industrial air pollution with 72 chemicals being let out as waste out of these 30 of them are can ‘t be removed.

There are many sources of gases that pollute our atmosphere. The sources of such gases are broadly divided into Primary pollutants (I), and Secondary pollutants (II). The primary pollutants are oxides of nitrogen and other Sulphur and hydrocarbons emitted when the fuels are being burned. There are also secondary pollutants which are formed due to physical processes and chemical reactions, one such compound is the ozone. In the textile industry coal and water are used which will generate steam comprising of carbon, carbon dioxide, carbon monoxide and Sulphur polluting the air to greater extent.



4. Risk Management

    1. Context: Understand the environmental pollution protection objectives and the national security circumstances.

2. Identification: Find, recognize and describe possible risks.
3. Analysis: Comprehend the nature of all possible risks and determine the level of each risk.
4. Evaluation: Compare the risk results of risk analysis with risk criteria to determine whether the risk is acceptable or not.
5. Response: Modify the risk by mitigating, avoiding, transferring or accepting the risk.
6. Monitoring: continually check the status of a risk to identify change from the performance level required or expected.
7. Reporting: share the situation reports with authority, industry, and society regarding the current state of risks and their management.

5. Risk Management Process

5.1. Risk Categories

1- Emission of CO gas

2- Emission of CO_2 gas

3- Emission of CH4 gas

4- Emission of CH_3CH_2OH gas

5- Emission of NH_3 gas

5.1.1. Risk Description and Cause

a) The following table summarizes the EECE program risk description and causes, showing the Likelihood and Impact factors of each assumed risk.

	HEADLINE RISK	DESCRIPTION OF RISK	INHERENT RISK FACTOR	IDENTIFY EXISTING CONTROLS & EFFECTIVENESS OF MITIGATION	RESIDUAL RISK FACTOR

1	Emission of CO	The significant increase in the number of motor vehicles	L3 Likelihood I1 Impact	Setting and creating regulation	3 L (3) I (1)
2	Emission of CO_2	Rising number of factories that Burn fossil fuels and manufacture cement	L5 Likelihood I4 Impact	Reporting to the authorities for any violation	20 L (5) I (4)
3	Emission of CH_4	Natural gas system and petroleum factories	L4 Likelihood I5 Impact	Reporting to authorities, keep the factory under monitoring and alarming residents	20 L (4) I (5)
4	Emission of CH_3CH_2OH	The increase of gasoline manufacturing	L2 Likelihood I3 Impact	Giving a fine to violated factories to keep the level of this gas under the threshold	6 L (2) I (3)
5	Emission of NH_3	fertilizer in agriculture industry	L1 Likelihood I2 Impact	Reducing the agriculture industrial activity	2 L (1) I (2)

b) The Likelihood degree and Impact factor given in the above table are described in the following table shown below.

Score	Likelihood (.)	Definition	Impact (.)	Descriptor
5	Highly likely to occur in normal circumstances	Very High Above 80%	Critical damage, huge impact	Catastrophic

4	Likely to occur in normal circumstances	High 60-80%	Major damage, high impact	Critical
3	Likely to occur in some circumstances	Medium 40-60%	Noticeable damage, high Impact	Significant
2	Unlikely to occur in normal conditions	Low 20-40%	Minor damage, minor Impact	Marginal
1	Only occur in exceptional circumstances	Very low Less than 20%	Insignificant damage, no Impact	Negligible

c) Finally, the risk matrix is shown below.

Risk Matrix		**Impact Factor**				
		1 Insignificant	**2 Minor**	**3 Moderate**	**4 Major**	**5 Catastrophic**
Likelihood	**5 Certain**	**5**	**10**	**15**	**20 (2)**	**25**
	4 Likely	**4**	**8**	**12**	**16**	**20 (3)**
	3	**3**	**6**	**9**	**12**	**15**

	Possible	**(1)**				
	2 **Unlikely**	**2**	**4**	**6** **(4)**	**8**	**10**
	1 **Rare**	**1**	**2** **(5)**	**3**	**4**	**5**

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